

KODAK CUSTOMER SERVICE PAMPHLET

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# ASTROPHOTOGRAPHY BASICS

•GETTING STARTED •ECLIPSES



AC-48



## ASTROPHOTOGRAPHY BASICS

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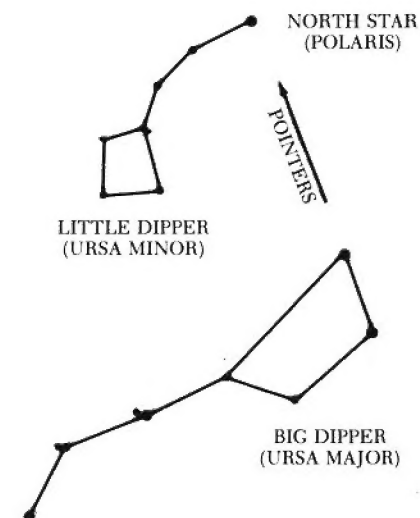
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Man has wondered and speculated about his universe through the ages. Now that space exploration is a reality, public interest has increased enormously. People the world over are combining their own ingenuity with the capabilities of modern optics and photographic materials in order to increase their knowledge of the universe through the medium of astrophotography. Besides being educational, astrophotography is an entertaining hobby, ideal for experimentation.

So that you can enjoy the fun of astrophotography and take rewarding pictures of celestial objects, we want to help you become familiar with the principles of astronomical picture-taking. This pamphlet will give you a good understanding of this fascinating field of photography.

## CHAPTER I — GETTING STARTED IN ASTROPHOTOGRAPHY

### Stationary Camera

You can start taking astrophotographs with an interest in astronomy and a minimum of equipment. All you need is a camera that can make time exposures, a cable release, a rigid tripod, and film.

Since many of your pictures will be time exposures, one of the most important requirements for astrophotography is a steady camera support. Therefore, place your camera onto a rigid tripod before taking pictures. Also use a cable release. This will help you get sharp pictures by keeping camera vibration to a minimum when you open and close the shutter.

To determine the best exposure for your equipment, make test pictures.

**Star Trails.** Bright stars are good subjects for your first astronomical picture-taking experience because they are easy to photograph. Stars do not remain stationary in the sky. They appear to rise and set because of the rotation of the earth. When you take time exposures of stars, you will discover that stars create interesting lines called star trails on your film.

So let's take some pictures. Load your camera with a fast film such as KODAK Tri-X Pan Film. Set the camera lens at its maximum opening and the focus at infinity. With your camera on a tripod, aim it toward a group of stars and open the shutter for a 4-minute exposure. At the end of the exposure, close the shutter.

After your film has been processed, you will find that the stars have been

recorded as a series of streaks or star trails. From these star trails you can determine the next exposure. If the trails are needle-sharp, you know that your lens is in sharp focus at the infinity setting. If the trails are straight and not jagged, you know that your camera support is sufficiently rigid.

You can use longer exposures and get the best pictures on dark, moonless nights away from the bright lights of cities. Moonlight and city lights produce a general background light in the night sky. This skylight limits the maximum exposure time that you can use without overexposing the background areas of your pictures.

Be sure to keep your camera lens free of dew from the night air. A lens cap is helpful in keeping dew off the lens between exposures. If you don't have a lens cap, you can make one from cardboard. When dew gets on the lens, wipe the lens surface with a clean, soft, lintless cloth or KODAK Lens Cleaning Paper. However, don't clean the lens while you're making an exposure.

You can obtain interesting circular star trails by photographing the sky area around the North Star. The North Star, called Polaris by astronomers, is located near the earth's celestial pole-point. The earth rotates around the celestial pole-point at the rate of 15 degrees per hour, or 1 degree every 4 minutes. This causes the stars to appear to rotate around Polaris. (To find Polaris, see the diagram on page 3. Turn the diagram, if necessary, in order to orient it correctly with the stars in your sky.) Polaris is the star at the end of the handle of the Little Dipper constellation called Ursa Minor.

If you make a time exposure of 5 minutes or more of the area of the sky that includes the star Polaris, your photograph will show circular star trails made by the stars revolving around Polaris. (See top picture on front cover.) Since Polaris is about 1 degree away from the true celestial pole-point, your photograph will show that Polaris has also made a short trail.

For other fascinating picture-taking possibilities, try some pictures of constellations such as the Big Dipper, Orion, or Cassiopeia. Try exposures of 5, 10, or 15 minutes, with the lens wide open. You can add interest and dimension to your astronomical photographs by including silhouettes of objects such as trees, your home, a church, or a landscape in the foreground of your pictures.

You can take beautiful pictures of celestial objects in color or black-and-white. Since your eyes have low sensitivity to color when they become adapted to the dark, you may not realize that the stars have different colors. You can capture the colors of stars with color film, such as KODAK EKTACHROME 200 Film (Daylight) for color slides or KODACOLOR 400 Film for color prints. Set your camera lens wide open and expose for 10 to 30 minutes or more. The longer the exposure, the longer the star trails will be on your film. If you wish to avoid recording trails, use an exposure of 30 seconds or less.

To make constellations stand out more when you project color slides, put a tiny needle-prick through the beginning of the trail of each star that makes up the constellation.



Bennett's Comet

Photograph by Michael D. Porter, Salt Rock, West Virginia

**Comets.** When a bright comet is due to appear in the sky, it is an event that makes the headlines. Some comets appear regularly, having a cycle of several years; others appear only once. You may be able to photograph them while they are visible for a period of a few days or weeks.

To photograph comets, use a fast film, open the camera lens all the way, and expose the film for 10 to 30 minutes. With a stationary camera, you will get a blurred image of the comet because of the rotation of the earth. For sharper pictures, follow the comet by using a guided camera; see page 9.

METEOR SHOWERS AND WHEN THEY OCCUR	
Name of Meteor Showers	Occurrence
Quadrantids	January 1—4
Lyrids	April 19—23
Eta Aquarids	May 1—6
Delta Aquarids	July 26—31
Perseids	August 9—15
Orionids	October 18—23
Leonids	November 14—18
Geminids	December 10—13

**Meteors.** Photographing meteors is a challenge and takes a great deal of patience. Although they appear much more often than comets, the position of meteors in the sky is unpredictable; they appear in all parts of the sky. You can take pictures of meteors in the same way as you photograph star trails, closing the shutter after a bright meteor has crossed the camera field of view.

Meteors vary greatly in brightness and frequently in color. These small bits of matter enter our atmosphere at about 25 miles per second and burn at only 50 to 70 miles above the earth's surface.

On a clear, dark night away from city lights, you may see about 5 to 10 meteors an hour. Dark, moonless nights are best for observing and photographing meteors.

There are certain periods of the year when meteor showers occur. The showers may last for several hours or a few days, but each meteor will be visible for only a few seconds. If you find out when meteor showers are due and where to look in the sky, you may have a chance to photograph them.

When a spectacular meteor shower is expected, your local newspaper may publish the date in advance. The table above indicates the times of the year when meteors are most likely to appear. The best time is after midnight because then we are on the leading side of the earth.

**Aurorae.** The Northern Lights (or the Southern Lights) vary greatly in form, intensity, color, and height. They are difficult subjects for color or black-and-white pictures. To photograph an auroral display, set your camera lens at its widest opening, and use a fast film such as KODAK TRI-X Pan Film for black-and-white prints or KODAK EKTACHROME 200 Film (Daylight) for color slides.

If you use EKTACHROME Film in 135 size, you should request special processing by Kodak, which increases the film speed 2 times. To obtain the special processing, buy the KODAK Special Processing Envelope, ESP-1, from your

photo dealer. Complete instructions come with the envelope. Other processing laboratories may also process the film to the increased speed.

Since an auroral display has such a wide range of intensity and brightness, exposure times can vary from 1 second to 2 minutes. In order to increase your chances of getting a good picture, take pictures at several different exposure times. Some aurorae move faster than others and require shorter exposure times. Blurring will occur if the light pattern moves during exposure, so the shorter exposures will yield sharper pictures.

**Man-Made Satellites.** The appearance of satellites is very predictable, since they orbit the earth every 90 minutes or so.

You won't get any detail in photographs of satellites when you use a telephoto lens or a telescope because satellites are too small and far away. Pictures of satellites will be better if you use a normal-focal-length lens on your camera because they will include more of the satellite path. This will make it easier for you to aim your camera toward the passing satellite. In addition, you can use longer exposures, since it takes longer for the satellite to move across the camera field of view. Finally, a normal-focal-length lens minimizes the effects of camera vibration.

To take pictures, load your camera with a fast film and set the lens wide open. When the satellite comes into view, point your camera toward the satellite path. (It will be too dark to use your viewfinder.) Open the shutter on B

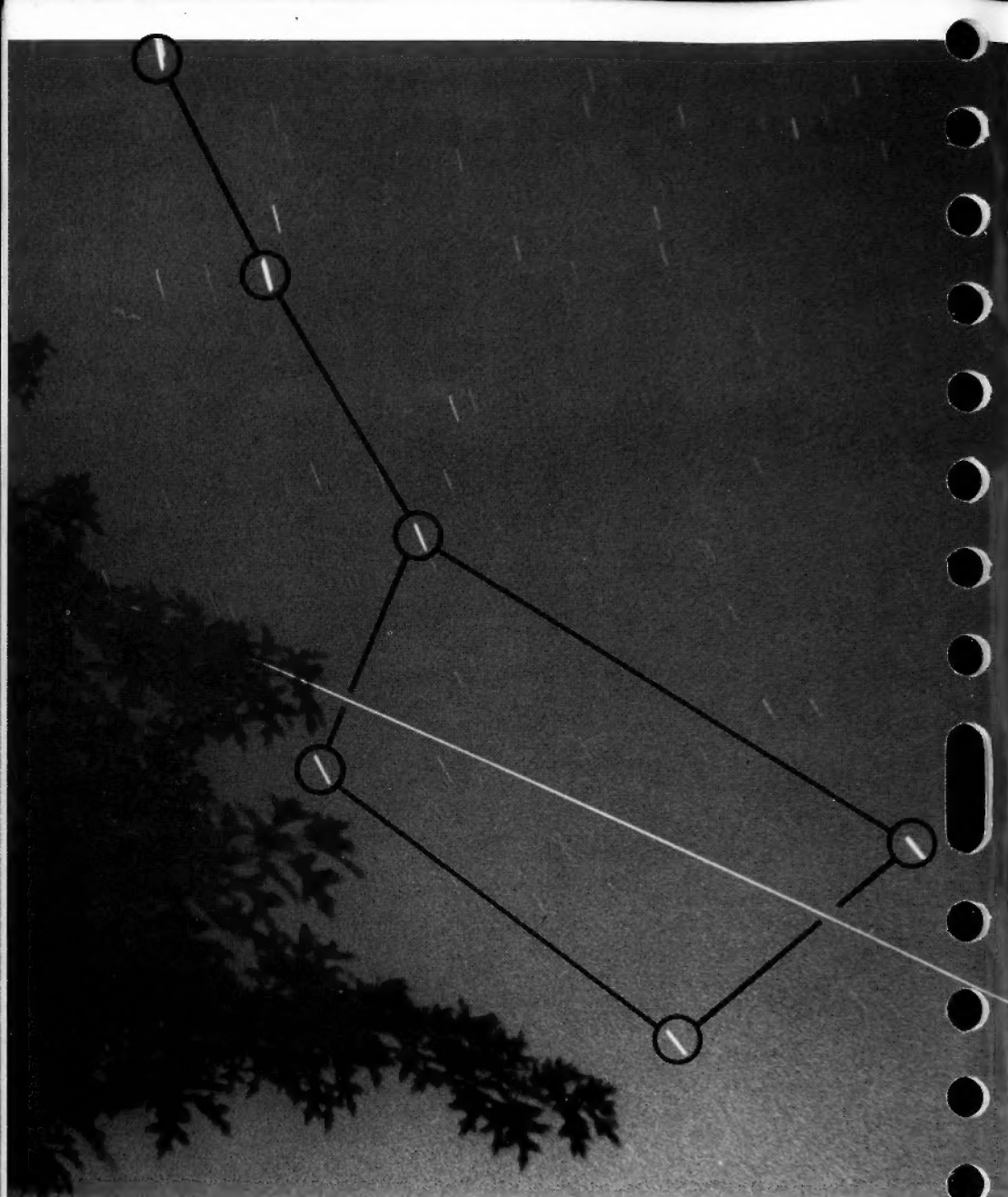
(Bulb) or T (Time), and wait until the satellite passes out of your camera field of view. Then close the shutter. You can make your picture even more impressive if you plan the timing so that you take the picture as the satellite passes through or near a prominent constellation.

**The Moon.** Since the moon is our closest celestial neighbor, it presents exceptional opportunities for astrophotography. The full moon requires the same exposure as a sunlit subject here on earth. The gibbous moon (between half and full) requires two times as much exposure as a full moon (1 stop more); the quarter phase (half-moon) requires four times as much exposure as a full moon (2 stops more); and a crescent moon (less than half) requires ten times as much exposure as a full moon (3 1/2 stops more).

Although the moon appears large to your eye, it is a very small subject to photograph. For example, with a 50-mm camera lens, the image of the full moon will be less than 1/50 inch (0.5 mm) on your film, hardly more than a speck. But you can take excellent pictures that will show some surface detail if you use a lens of at least 12 inches (305 mm) focal length and make a photographic enlargement to gain additional magnification.

You can determine in advance the approximate diameter of the moon's image that you'll get on your film by dividing the focal length of your camera lens by 110. Use the same units—inches or millimeters—for both the image diameter and the focal length.





With proper timing, you can photograph a man-made satellite crossing a familiar group of stars. Here, Echo II passes through Ursa Major. KODAK Tri-X Pan Film, 50-min lens at  $f/2.8$ .

Photograph by Don C. Ryon, Rochester, New York

### Sky Charts and Astronomical Tables

Sky charts, such as those published in *Sky and Telescope* and *Astronomy* magazines each month and in many local newspapers each week, indicate the positions of celestial objects and the times that they are visible. When you use a sky chart, imagine that the chart is pasted on the ceiling so that the compass directions agree with your location. The stars on the chart will then appear in their correct positions.

A *Rotating Star and Planet Finder* is a helpful guide for locating celestial objects. When the dial is set for the month, day, and hour, the dial indicator shows all of the constellations overhead. See Scientific-Supply Sources.

*Graphic Time Table of the Heavens* is a chart published annually by the Maryland Academy of Sciences. It includes the rising and setting times of celestial objects and other astronomical information.

### Guided Camera

So far we have been talking about stationary cameras. You can improve your astrophotographs by using your camera on an equatorial mount in order to follow the motion of astronomical subjects. This compensates for the rotation of the earth and keeps the images stationary on your film during the long exposures that may be necessary for pictures of faint objects. An equatorial mount provides a heavy, firm support and orients your camera for convenient tracking of celestial objects. You can purchase an equatorial

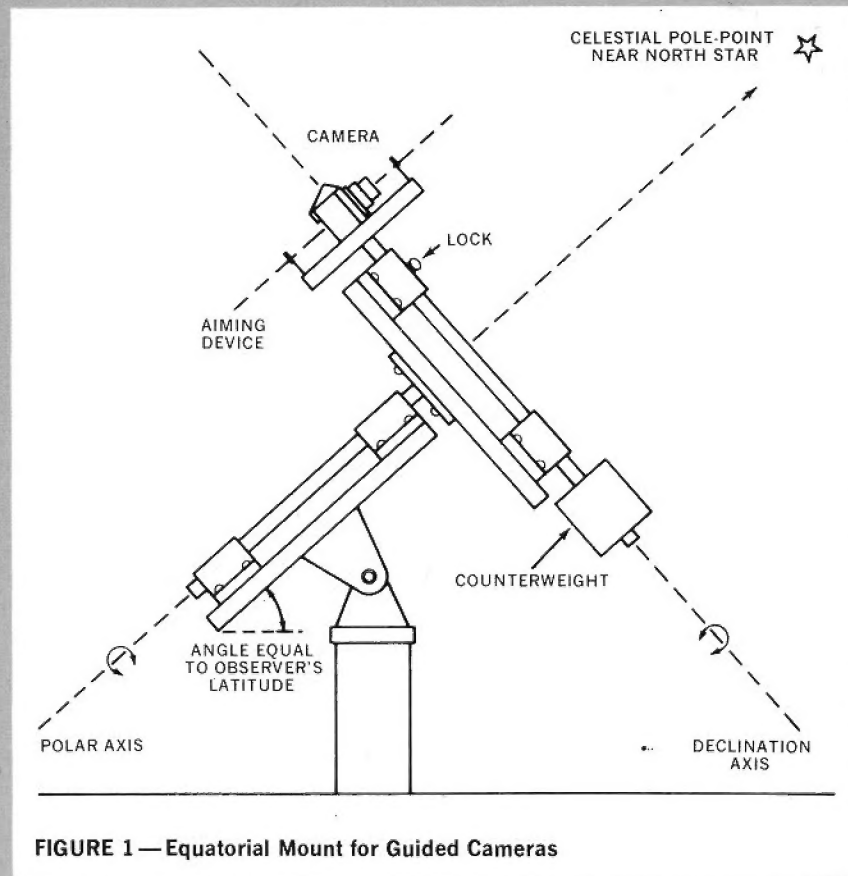
mount, without motorized drive, reasonably from scientific-supply firms. Motorized drive, however, works better.

### How To Use an Equatorial Mount.

(Refer to figure 1.) Set the polar axis parallel to the earth's axis by pointing it at the celestial pole-point near the North Star. When you do this, the angle between the polar axis and the horizontal will be equal to the latitude of your location. You can measure this angle with a protractor and a level. Once you have properly aligned the polar axis, you won't have to change it unless you move the telescope to another latitude.

Next mount the camera at the end of the declination axis as shown in figure 1. Point the camera toward the object you want to photograph and lock the declination axis. Now by rotating only the polar axis, you can follow the motion of an astronomical subject accurately. An aiming device aligned parallel to your camera lens axis will help you center your camera on the subject. You can use a simple aiming device made from two screw eyes available from hardware stores, but a small telescope or binocular attached near the camera will be more satisfactory.

If you guide your camera carefully, stars will appear as points of light of very small diameter. The brighter stars, however, will produce larger images because of light spreading in the film. You cannot magnify star images with long-focal-length lenses because stars are much too far away from us. However, the moon and planets do have definite image diameters. When



you photograph these subjects, you can obtain larger images by using a telephoto or long-focal-length lens on your camera.

### Telescope or a Binocular

To photograph astronomical subjects in greater detail, you will need a telescope. There are two major classes of telescopes: refracting and reflecting. The refracting telescope forms an image of an object by transmitting the light rays through a lens system similar to camera or binocular lenses. The reflecting telescope collects the light rays with an accurately curved mirror which forms the image. With both telescopes, the primary image is magnified by an eyepiece. Reflecting telescopes are less expensive and are generally better at focusing different colors in the same plane. This feature is important in obtaining sharp images.

Astronomers use the term objective lens or objective when they refer to the telescope main or primary lens which collects the light from the subject. The objective may be either the objective (front) lens of a refracting telescope or the mirror of a reflecting telescope. When we discuss telescope lenses in more detail, we will use these terms.

**Telescope Mounting and Drive System.** An equatorial mounting with a motorized drive system will allow you to use the long exposures that are necessary for astrophotography of many interesting objects far out in space. This equipment will permit the recording of planets, nebulae, galaxies, and star clusters. Equatorial mounts

with clock drives are available reasonably from scientific-supply firms.

Operating a motorized mount is similar to operating a simple equatorial camera mount. Turn the telescope about the declination axis to the desired position, and lock the declination axis. The motor drive will rotate the telescope and declination axis about the polar axis in order to keep the desired object in view and stationary on your film. You can take pictures of brighter objects without using a drive system, but a drive system is almost a necessity for photographing faint objects requiring long exposures.

When you use a drive system, set it to rotate the polar axis one revolution per day. Professional astronomers rotate the polar axis of their telescopes once every sidereal day (23 hours, 56 minutes, and 4 seconds of clock time), which is the true rotational period of the earth. However, even their guiding mechanisms are not perfect. Refraction by the earth's atmosphere changes the apparent position of celestial objects; therefore, slight guiding corrections are required. An ordinary 24-hour clock drive is good enough for most astrophotography; you can correct for the slight guiding discrepancy manually, if necessary.

To observe the tracking accuracy of your drive system, you can view the object relative to the cross hairs of a reticle used with an illuminated eyepiece on your telescope, or you can use a guide telescope aligned with the main scope. In addition, a small finder telescope is often necessary to help you locate celestial objects because the field of view of the high-power main scope is extremely small.

**Telescope and Camera.** The four basic telescope-camera systems are (1) eyepiece-camera lens, (2) eyepiece projection, (3) prime focus, and (4) negative-lens projection (figure 2, page 16). The system you use depends primarily on your equipment and on the desired image size.

The *eyepiece-camera lens system* is probably the most convenient for those who are new to astrophotography because you don't need a special camera or a camera with a removable lens. You can take astrophotographs with an ordinary camera positioned close to the eyepiece of your telescope. However, when using this system you may find it difficult to check alignment and focus. Image contrast may be reduced by reflections from the many lenses in the light path.

There are several kinds of optical instruments that you can use for the telescope part of your eyepiece-camera system. These include binoculars and spotting scopes as well as astronomical telescopes with eyepieces. To take pictures with your camera and telescope, you'll need a simple mounting device to attach the two units. The mounting device should provide both precise alignment of your camera lens with your telescope eyepiece and a rigid, vibration-free support for your camera. Although the mount should furnish a lighttight guard between the two units, this guard is not absolutely necessary. A black, lintfree cloth will do. You can purchase mounting devices inexpensively from optical-supply firms.

With the other three telescope-camera systems, you do not use your camera lens. Therefore, you'll need a camera

with a removable lens and a shutter that's built into the camera body. The camera body you use should have some provision for focusing on a substitute film plane. (See section on focusing, page 13.) Cameras that do not fulfill these requirements must be altered.

An excellent camera for astrophotography with a telescope is the single-lens reflex camera with a removable lens. You can use this type of camera with all four telescope-camera systems by using the camera with or without its lens, depending on the system you employ. When you look through the viewfinder of a single-lens reflex camera, you are looking through the lens system. This enables you to position the image and focus your telescope-camera system conveniently and accurately.

You can purchase specially built astrocameras from telescope manufacturers.

With the *eyepiece-projection system*, you attach your camera, with its lens removed, to the telescope eyepiece. The eyepiece projects the image directly onto the camera film plane. Since you don't use the camera lens, there are fewer lenses for the light to pass through. As a result, less light is absorbed and there are fewer lens aberrations to affect the image.

Also, with the eyepiece-projection system you can increase magnification by moving the film plane farther from the eyepiece. However, as you do this, the image-forming light is spread over a larger area. This fainter image requires a longer exposure.

To focus the image on the film plane, it's necessary to move the eyepiece outward slightly from the setting for visual use. See Focusing Procedure.

In the *prime-focus system*, the objective of the telescope focuses the image directly on the camera film plane, thus eliminating extra lenses. Consequently, this system yields small images of maximum contrast, sharpness, and brightness.

The *negative-lens projection system* is similar to the prime-focus method, but a negative achromatic lens, usually referred to as a Barlow lens, is placed inside the focus of the objective. This lens magnifies the image without greatly increasing the length of the telescope. This principle is used in telephoto lenses.

**Focusing Procedure and Camera Alignment.** The way in which you check for alignment and sharp focus of your telescope and camera will depend on the type of camera you use.

With a single-lens reflex camera and a suitable mount, line up your camera so that the film is centered at right angles to the optical axis of your telescope. If you use the camera lens, place it close to the eyepiece of the telescope. Next put a piece of tracing paper or tissue paper over the front of the main tube of your telescope, and illuminate it evenly with a 100-watt light bulb in a reflector about 2 feet away. Set the camera lens at its smallest opening. Then move the camera back and forth slightly to obtain the most uniform illumination in your viewfinder. If the camera lens is either too close or too far from the eyepiece of the telescope, the corners of the viewfinder will be dark.

For focusing, take the paper off the end of the telescope and point the telescope toward a bright astronomical subject, such as the moon or a bright

star, NOT THE SUN! If you use the camera lens, open the lens to its maximum opening and set the lens for infinity. Then adjust the focus with your telescope (or binocular). When the image looks sharp on the ground glass of your viewfinder, it will be sharp on your film.

With a nonreflex camera, use the same mounting setup and alignment procedure. To align and focus this type of camera, you will need a piece of ground glass to fit the film plane of your camera. Ground glass is available through your photo dealer or from scientific-supply firms. You can use a piece of wax paper or matte acetate (thin plastic sheeting which has a matte surface) as a substitute, but be careful not to bend it; the wax paper or matte acetate must be flat in the film plane.

Before loading this type of camera with film, open the camera back and place the ground glass over the film plane of the camera, with the ground surface toward the lens. Make sure that the glass is resting on the film-plane frame or rails; then fasten it in place with tape.

Open the camera shutter on T (Time) or B (Bulb). If you use the B setting, use a locking cable release to keep the shutter open. Then with the camera lens wide open and set on infinity, adjust the focus with your telescope and observe the image on the ground glass with a magnifier, such as the KODAK Achromatic Magnifier, 5X. When the image appears in sharp focus on the ground glass, it will be sharp on your film. After focusing, lock all adjustments and remove the ground glass. Then load your camera with film. Be careful not to disturb the focus.



**Lens Speed.** The lens speed of a telescope-camera system indicates its light-gathering capability. This is expressed by *f*-number or objective diameter, depending on the subject you are photographing.

In astrophotography there are two kinds of subjects—extended objects and point-source objects. Extended objects appear large enough so that their images cover an appreciable film area. For example, the moon, sun, planets, and large nebulae are extended objects. Point-source objects, such as stars, make a tiny image the size of which is nearly independent of lens diameter or focal length.

When you photograph extended objects, as in conventional photography, the light reaching the film in your telescope-camera system compared to another telescope-camera system is inversely proportional to the ratio of their *f*-numbers squared. For example, the image from an *f*/4 telescope-camera system is 4 times brighter than the image from an *f*/8 system;  $\frac{f/8^2}{f/4^2} = 4$  times. A picture taken at *f*/4 requires an exposure time 1/4 as long as a picture taken at *f*/8.

However, when you take pictures of point-sources (stars), the image intensity that reaches your film depends upon the diameter of the telescope or binocular objective, *not the f-number*. In this situation the lens speed of telescope objectives is directly proportional to the ratio of the squares of their diameters. A 3-inch objective transmits 2.25 times as much light as a 2-inch objective;  $\frac{3^2}{2^2} = \frac{9}{4} = 2.25$  times. Your exposure time will be  $\frac{1}{2.25}$  as long with the 3-inch objective.

**The *f*-Number of Your Telescope-Camera System.** The *f*-number of your system is determined by your telescope (or binocular). When you take pictures through a telescope and you use your camera lens, set the camera lens at its widest opening.

The formulas and diagrams in figure 2 will help you determine the effective *f*-number of each of the telescope-camera systems. With the eyepiece-camera lens system, you can use the formula that includes telescope power if you don't know the focal length of your telescope objective or eyepiece but you do know the power of your telescope, spotting scope, or binocular.

#### Apparent Brightness of Astronomical Subjects

The Greek astronomer Hipparchus devised a system of classifying stars according to degree of brightness, which is still in use today. He designated the 20 brightest stars as *first* magnitude; the next 50, in order of brightness, as *second* magnitude; and so on. Stars that are barely visible to the normal, unaided eye are *sixth*-magnitude stars. The sun, moon, and some planets are brighter than first-magnitude stars and have negative magnitudes. For example, the brightness of the sun is -26.7.

This brightness relationship is useful because it can help you determine exposure time. Each magnitude difference of 1.0 indicates a brightness difference of 2.5. For a given astrophotographic setup, this means that fourth-magnitude stars will require 2.5 times the exposure time of third-magnitude stars, and so on. Textbooks

on astronomy in your public library contain tables of relative magnitudes for various celestial objects. You can estimate magnitude classification to a high degree of accuracy by comparing the object of interest with objects of known magnitude.

#### Estimating Exposure

General exposure recommendations are given in the table on page 19. Since there are so many variables in taking astrophotographs, such as equipment, speed of the film, and atmospheric conditions, the table gives exposure ranges to serve as a basis for your own pictures.

You may find exposure data with astrophotographs in books and magazines. You can relate these data to your own astrophotography setup. For example, assume that the exposure for a photograph of the moon is given as 1/125 second at *f*/8 with KODAK PANATOMIC-X Film (ASA 32). If your telescope-camera system has an effective *f*-number of *f*/32 and you are using KODAK PLUS-X Pan Film (ASA 125), what should your exposure time be?

Since the moon is an extended object, the normal *f*-number relationship is

valid. Therefore, to determine the exposure compensation for the smaller *f*-number of your system, use formula 1 below.

In this instance  $\frac{32^2}{8^2} = 16$ ; therefore, your system requires 16 times as much exposure. However, your film is 4 times as fast as the film used in the example, so it requires 1/4 of the exposure. Combine both factors by multiplying  $1/4 \times 16 = 4$ . This calculation indicates that you need 4 times as much exposure as was used in the example. To determine your exposure time, multiply the exposure time used in the example by 4. Since  $4 \times 1/125$  second =  $1/30$  (approximately), the exposure time for your setup is 1/30 second.

In star photography the diameter of your telescope or binocular objective, not the *f*-number, determines the intensity of the light that reaches your film. Consequently, exposure data for photographs of point-source objects should include objective diameter rather than *f*-number. To compute the exposure compensation for differences in objective diameter, use formula 2.

Then multiply the exposure time used in the example by the exposure compensation. Also compensate for differences in film speed, if any.

#### FORMULA 1

$$\frac{(\text{f-number for your system})^2}{(\text{f-number for example})^2} = \text{exposure compensation}$$

#### FORMULA 2

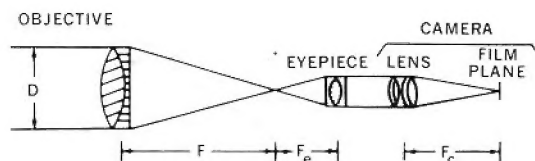
$$\frac{(\text{objective diameter for example})^2}{(\text{objective diameter for your system})^2} = \text{exposure compensation}$$



### EYEPIECE-CAMERA LENS

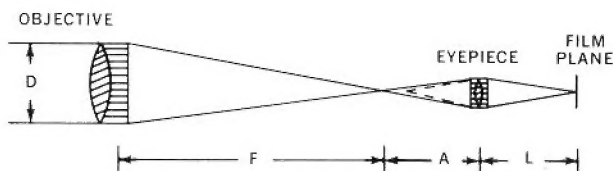
$$f\text{-number} = \frac{F \times F_c}{D \times F_e}$$

$$\text{or } \frac{\text{Telescope Power} \times F_c}{D}$$



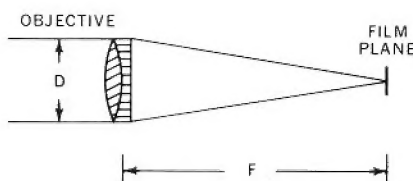
### EYEPIECE PROJECTION

$$f\text{-number} = \frac{F \times L}{D \times A}$$



### PRIME FOCUS

$$f\text{-number} = \frac{F}{D}$$



### NEGATIVE-LENS PROJECTION

$$f\text{-number} = \frac{F \times C}{D \times B}$$

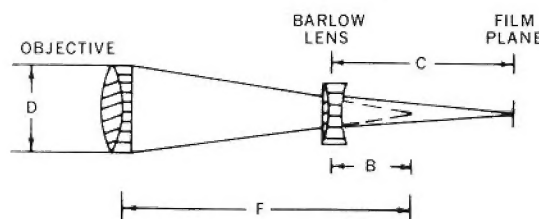


FIGURE 2—Telescope-Camera Systems

Where

F = focal length of the telescope objective

F<sub>e</sub> = focal length of the eyepiece

F<sub>c</sub> = focal length of the camera lens

D = diameter of the telescope objective

L = distance of eyepiece from the film (eyepiece projection only)

A = distance of eyepiece from normal focus of the telescope objective (eyepiece-projection system only)

C = distance of Barlow lens from film

B = distance of Barlow lens from normal focus of telescope objective

Telescope power = power printed on the telescope eyepiece, on the binocular, or given in the instruction manual for the equipment.

Note: Use the same units for all dimensions.

### Film Selection

Film speed is an important consideration in astrophotography as a fast film requires less exposure time. Shorter exposures minimize the effects of guiding errors and atmospheric shimmer, factors that reduce image sharpness. The film speed is listed on the instruction sheet which comes with the film.

The response of a film is directly proportional to its film speed. For example, a film with a speed of ASA 400 is 5 times as fast as a film with a speed of ASA 80;  $\frac{400}{80} = 5$ . Consequently, the exposure time for the 400-speed film would be 1/5 as long as the exposure time for the 80-speed film.

Speeds of films for pictorial photography are based on average exposure times used in taking conventional pictures. If your calculated exposure time is much longer than 1/10 second, you should regard your exposure estimate as the basis for trial only. So make a series of test exposures at 1/4, 1, 4, and 16 times the calculated exposure. Corrections for long exposures with Kodak films, up to 100 seconds, are given in Kodak pamphlets listed on page 32.

Film graininess is also an important factor to consider in selecting a film for astrophotography. Graininess is the salt-and-pepper appearance or sand-like pattern that is sometimes evident in enlarged photographs. Usually, slow-speed films have the finest grain. If you plan to enlarge your astrophotograph, it is best to use the finest-grain film you can. However, the film you select should have not only fine grain but also

adequate speed for your picture-taking situation. See film suggestions on page 28.

### Camera Filters

You can take excellent astrophotographs without using filters, but sometimes filters may help reduce the effect of background light. Moonlight scattered by the earth's atmosphere produces a predominantly blue skylight. If your exposure time is long enough, this light causes overexposure in the sky areas of your picture. You can use filters to reduce the effect of background light. With panchromatic black-and-white film use a No. 8 yellow filter or a No. 15 deep-yellow filter over the camera lens. This will permit you to use longer exposure times without overexposing the background areas of your picture. Since filters decrease the intensity of the light reaching your film, increase your exposure time by the filter factor listed on the instruction sheet that comes with the film or the filter. Camera filters are generally not used with color films.

### Film Processing

You can have your Kodak color film processed by Kodak or another laboratory, or you can process it yourself. For Kodak processing, see your photo dealer, or you can mail your color film directly by purchasing Kodak Mailers. Kodak doesn't process black-and-white film, but photofinishers offer this service.

When you have your film processed, request that it be returned to you uncut and unprinted or unmounted. The photofinisher may think that star images are just dust spots or have difficulty locating the picture areas and cut right through pictures without realizing it. As an aid in identifying your film, photograph a full-frame card showing your name and address on the first frame.

After your film has been processed, you can draw lines across the film with a ball-point pen or a felt-tip pen to show the negative areas to be printed. You can cut your slides apart by hand and mount them in KODAK READY-MOUNTS, available from photo dealers. For information on how to process your own films, see the list of Kodak publications.

Aurora Borealis, KODAK High Speed EKTACHROME Film (Daylight), 20 seconds  $f/2$ .  
Photograph by Robert L. Clemens, Rochester, New York



# EXPOSURE GUIDE FOR BASIC ASTROPHOTOGRAPHY

SUBJECT	INSTRUMENT	MOUNT	OBJECTIVE	f-NUMBER	FILMS	EXPOSURE
Star Trails and Comets	Camera with time exposure	Rigid support	Any lens	Wide open	Fast, B & W and color	Up to 30 min or more
Meteors	Camera with time exposure	Rigid support	Good wide-field lens	$f/6.3$ or wider	Fast, B & W and color	10 to 30 min
Aurorae	Camera with time exposure and fast lens	Rigid support	Fast lens	$f/4.5$ or wider	Fast, B & W and color	1 sec to 2 min
Man-Made Satellites	Camera with time exposure and fast lens	Rigid support	Fast lens	$f/4.5$ or wider	Fast, B & W and color	Hold shutter open for duration of pass.
Moon	Camera or camera with telescope	Rigid or equatorial with or without drive	1" diameter or larger	$f/4.5$ or slower	Medium speed B & W and color	1/125 sec to 10 sec
Stars and Comets	Camera or camera with telescope	Equatorial with guiding sights	1" diameter or larger for fine detail	$f/6.3$ or wider	Fast, B & W and color	10 min to 1 hr
Star Clusters, Nebulae, and Galaxies	Camera or camera with telescope	Equatorial with sights and drive	1" diameter or larger	About $f/6.3$	Fast, B & W and color	10 min to 1 hr
Planets	Camera with telescope	Equatorial preferably with drive	1" diameter or larger; for detail, 6" and up	Use f-number determined by your system.	Fast, B & W and color	1/2 to 15 sec
Sun* (Never look at the sun through any optical device without adequate protection!)	Camera or camera with telescope	Rigid or equatorial with or without drive	Neutral Density Filters 4.0 — 6.0 over 1 to 4" main objective	$f/11$ — $f/32$	Slow, B & W and color	1/30 to 1/1000 sec with Neutral Density Filters 4.0 — 6.0 over main optical objective, not behind the eyepiece!

\*For protection in observing the sun, see page 20.

## CHAPTER II — SOLAR ECLIPSE

### PROTECT YOUR EYES DURING A PARTIAL SOLAR ECLIPSE!

**WARNING: BLINDNESS** will result from looking at the sun, either directly or through the viewfinder. Never look at the sun without adequate protection. Protecting your eyes adequately will reduce exposure to ultraviolet and infrared radiation, which can severely burn your eyes instantaneously without your immediately being aware of it. Also, adequate protection will increase eye comfort by reducing the intensity of the visible sun rays. **NO FILTER IS USED DURING THE TOTAL ECLIPSE.**

#### Viewing Filter for Partial Phases

Always use a filter that will absorb *equally* and *sufficiently* the ultraviolet, visible, and infrared energy of the sun.

Medical authorities indicate that a neutral density filter of metallic silver, such as developed black-and-white photographic film, of 6.0 density will provide protection. Such filters are not suitable for photographic use because they scatter light, causing a slightly unsharp image. It is convenient to staple the filter behind a slot cut in cardboard and hang the assembly on a string around your neck. Place the filter **IN FRONT OF** your eyes before facing the sun. Such a filter can be made with two thicknesses of *black-and-white* photographic film, such as KODAK VERICHROME Pan Film, which has been completely exposed and developed to maximum density. Expose the film by unrolling it in daylight; then develop the exposed film fully, according to the manufacturer's recommendations.

**Do not use color film or crossed polarizing material as a viewing filter.**

#### Focal Length of the Lens

The high light intensity of the sun permits you to use any camera. However, the size of the sun or moon image depends on the focal length of the camera lens. You can estimate the actual image size on the film by dividing the focal length by 110. For example, with a camera lens having a focal length of 4 inches (100 mm), the image size would be about 4/110 inch (1 mm) in diameter—the thickness of a dime. However, many good pictures of eclipses have been made with 35-mm cameras equipped with lenses of 2-inch (50-mm) focal length. So don't put your camera away because you don't have a long-focal-length lens.

In movies of the eclipse, the image will be enlarged when projected on the screen. Assuming a magnification of 110 diameters on projection, the diameter of the image of the sun on the screen will be approximately equal to the focal length of your camera lens.

#### Camera Protection

The sun can burn holes in focal-plane shutters, warp the leaves of between-the-lens shutters, and melt composition shutter blades. Use neutral density filters that are made *for photographic use*. If your camera must be pointed toward the sun throughout the eclipse, shade it between exposures. It is wise to shade the camera from direct sunlight at all times to avoid overheating film and camera.

#### Aiming Your Camera

**NEVER LOOK AT THE SUN THROUGH A CAMERA VIEWFINDER WITHOUT SUITABLE FILTERS.** This is especially important with single-lens reflex cameras, both still and movie. The best policy is to aim your camera without using its viewfinder. If you must use the viewfinder, use filters made from black-and-white film, as noted above, held *in front of the viewfinder or, with a single-lens reflex camera, in front of the camera lens.*

Filters made for photographic use give **NO VISUAL PROTECTION.** Therefore, use the exposed-film filters for visual aiming and change to neutral density filters made for photographic use to take pictures of the eclipse. Once you have changed to filters for use on your camera, do **not** look through the viewfinder.

#### Exposure

The light from the sun's surface is so intense that in order to photograph the partial phases of the eclipse, you must

reduce the sun's light by 10,000 to 100,000 times. Neutral density filters (ND) provide the most convenient way of cutting down the light to allow normal camera exposures. **During the partial phases, the light intensity of the surface of the sun is the same as it is when there is no eclipse.**

Here is a simple formula for determining the correct exposure for the partial phases:

$$f^2 = S \times t \times 10^{7-D}$$

where

- $f$  is the lens opening
- $S$  is the ASA speed of the film
- $t$  is the shutter speed in seconds
- $D$  is the density of the neutral density filter in use

For example, with a neutral density filter of 5.0, KODACHROME 64 Film, and a shutter speed of 1/125 second, you would use a lens opening of  $f/8$ ; with a shutter speed of 1/30 second, you would use a lens opening of  $f/16$ .

Additional exposure information is given in the table on page 27. If you are taking pictures with a simple nonadjustable camera, use KODAK VERICHROME Pan Film and a 6.0 ND (neutral density) filter during the partial phases. Remove the ND filter during totality.

The brightness of the sun does not change during the eclipse, so your exposure during partial phases should remain constant as long as sky conditions remain constant. Most camera exposure meters average the reading



over some area. If the visible portion of the sun does not cover all of this area, the meter will indicate more exposure than needed.

If you have a camera with automatic exposure control, consult your camera manual to override the automatic exposure system; or see your local camera dealer.

## What To Photograph During a Solar Eclipse

### Partial Phases

Beginning about 1 hour before totality, you can see the moon gradually encroaching on the sun's disk; for about 1 hour after totality, the shadow gradually retreats. You can obtain an interesting record of the eclipse by mounting your camera onto a firm support and making a series of exposures at 5-minute intervals on the same frame of film, starting a half hour before totality and continuing for a half hour after. For this technique, you'll need to use a camera which will let you take more than one exposure on the same frame of film. Check your camera manual to see if you can do this with your camera.

The period over which you can make such a record on a single frame depends on the angle of view of your camera lens. The position of the sun will change about 15 degrees per hour. A normal-focal-length camera lens will cover a sufficient angle for exposures over a 2-hour period. Watch your local newspaper for the timing of the progress of the moon across the sun disk; then plan your camera position and exposure schedule accordingly.

### Shadows Under Trees

All during the partial phases, the sunlight filtering through the leaves of trees forms images of the eclipsed sun on the ground. You can photograph these crescents easily with normal exposures for the film you're using.

### Shadow Bands

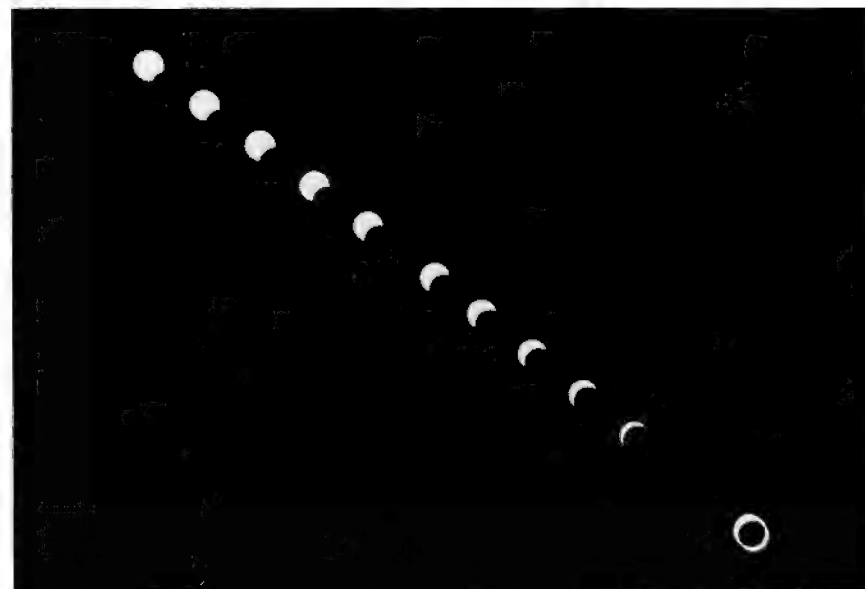
During the last few seconds before totality, you may see wave-like shadows called shadow bands moving over the ground. They average from 1 to 2 inches in width and are 5 or 6 inches apart. They are most easily visible on a white background, such as a bed sheet.

This phenomenon is *very difficult* to photograph because of the low illumination and the speed of movement. With a white sheet on the ground to obtain as high a reflectance as possible, you can expose KODAK Tri-X Pan Film at 1/125 second with a lens opening of  $f/2$ . If the largest lens opening on your camera is  $f/3.5$ , you can use KODAK Recording Film 2475 (ESTAR-AH Base) or KODAK ROYAL-X Pan Film to record the shadow bands.

### Landscape During Totality

The intensity of the available illumination varies rapidly during the minute just before, and the minute just after, totality. At the darkest period (during totality), an exposure of about 1/4 second at  $f/8$  on KODAK EKTACHROME 200 Film should give good results for landscape photography.

During totality, you may not be able to see the settings on your camera. Carry a pocket flashlight so that you can check or change your camera settings.



Multiple exposures show the progress of the eclipse in this picture made with a normal-focal-length lens. The eclipse was photographed at 5-minute intervals except for a 10-minute delay between the last two exposures.

### Total Eclipse

Totality usually lasts less than 5 minutes. Therefore, it is a good idea to go through a few practice runs and time yourself so that you can take several pictures during this brief period.

For movie cameras remove the filter and expose at the highest frame rate.

The diamond-ring effect can be achieved by adjusting exposure for the prominences and removing the neutral-density filter the *instant* before taking the picture.

**WARNING:** Do NOT remove the filter too soon! If you do, severe eye damage can result.

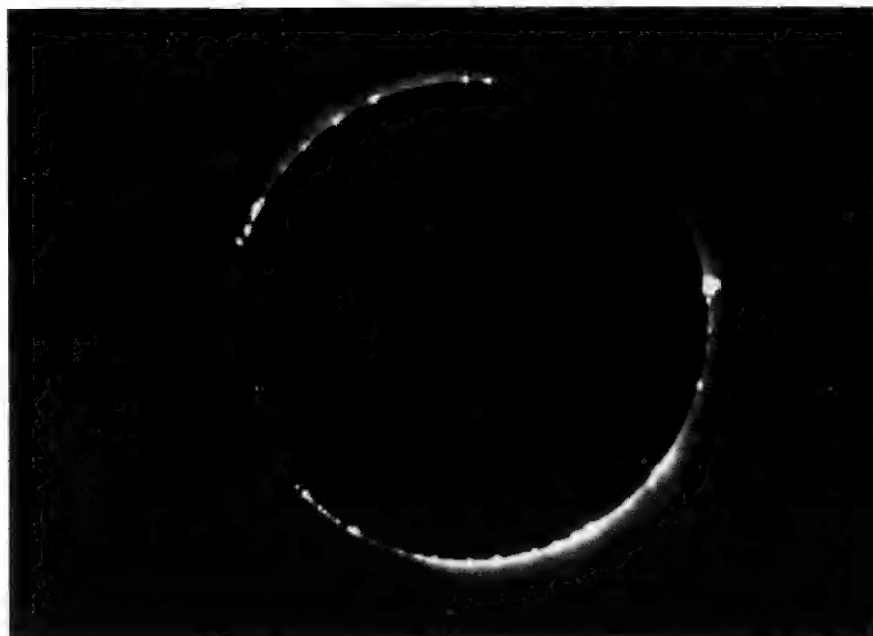
### Baily's Beads

For an instant just before totality and again just as the sun emerges, light breaks through the valleys on the rim of the moon, forming what looks like a beaded necklace along the edge of the moon. This brief display is very spectacular.

For still cameras, use a shutter speed of 1/500 second, no filter, and the same lens opening recommended for partial phases in the exposure table on page 27.

### Corona

At totality, the corona appears around the sun as a beautiful halo, decreasing in brightness from the moon's rim outward. Points of interest to observe and photograph in the outer corona are the equatorial streamers, which may extend several diameters from the sun. Superimposed on the inner corona are solar



For spectacular close-up views such as this one, which shows the solar prominences, take the pictures through a telescope with your camera.

prominences, scarlet, tongue-like jets shooting outward from the sun surface.

Since the intensity of the corona fades rapidly away from the solar limb (edge of the sun's apparent disk), the distance to which the photograph will show the corona depends on the exposure—the longer the exposure, the greater the extension. However, if you attempt to record the faint outer streamers, then the inner corona will be overexposed. The most colorful results are often obtained with a shorter exposure gauged to record the inner corona.

#### Telescope or a Binocular

You can use a small telescope or binocular in conjunction with an ordinary camera. The image size obtained

with such a combination will be equal to that obtained with your camera alone multiplied by the power of the telescope or binocular. It is best to build some type of rigid support to hold your telescope and camera in alignment.

You can arrive at the best focus and exposure for the partial phases experimentally by photographing the sun prior to the eclipse. Make an approximate focus setting by focusing the telescope or binocular on an object at a great distance. Then set your camera lens at infinity, and focus at the largest lens opening. Join the camera and telescope, covering the space between the camera lens and the eyepiece of the telescope with a black cloth to cut out stray light. See pages 12–16.

#### Camera Support

For a series of pictures of the partial phases, mount your camera on a tripod or other rigid support to prevent movement between exposures. See picture on page 23. Also, with long-focal-length lenses, a telescope or a binocular, a solid support is essential to avoid loss of definition due to camera motion.

Because of the earth's rotation, solar images 1 inch in diameter or greater will show significant movement on the film during exposures of 1/2 second or more. For these and longer exposures, use an equatorial mounting with a clock drive. If your exposures exceed 1 second and no drive mechanism is available, the diameter of the solar image should be proportionately smaller as exposure times are increased.

#### Filters

The use of neutral density filters is a convenient way of reducing the excessive light intensity for photography during the partial phases. You can quickly remove the filters from in front of the lens at totality. The viewing filters described on page 20 are not suitable for photographic use.

The KODAK WRATTEN Neutral Density Filters No. 96 (gelatin) is available in the following densities: 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.00, 2.00, 3.00, and 4.00. You can obtain intermediate densities or higher densities, such as 5.0 and 6.0, by combining two of the standard filters. However, if you use more than two at one time, image sharpness will be reduced. These filters are available through photo dealers.

#### Neutral Density Filters

Neutral Density	Filter Factor	Reduces Exposure by (f-stops)
0.1	1 1/4	1/3
0.2	1 1/2	2/3
0.3	2	1
0.4	2 1/2	1 1/3
0.5	3	1 2/3
0.6	4	2
0.7	5	2 1/3
0.8	6	2 2/3
0.9	8	3
1.0	10	3 1/3
2.0	100	6 2/3
3.0	1,000	10
4.0	10,000	13 1/3
5.0	100,000	16 2/3
6.0	1,000,000	20

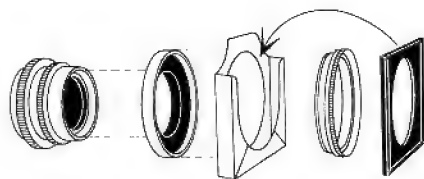
When you use neutral density filters, be sure you don't confuse their density values. For example, a 0.50 neutral density filter reduces the light by 3 times while a 5.0 neutral density filter reduces the light by 100,000 times!

Some neutral density filters are identified as 2X, 4X, 8X, and 10X. These designations indicate the filter factor and are equivalent to the following densities: 2X = 0.30, 4X = 0.60, 8X = 0.90, and 10X = 1.00. The filter factor indicates how many times the filter reduces the light. For example, a filter factor of 4 means that the filter reduces the light by 4 times.

*Be sure of terminology when ordering neutral density filters. Obtain a 4.0 filter, not a 0.40 or 4X filter.*

**WARNING:** Filters made for photographic use give NO VISUAL PROTECTION. Do not try to observe a solar eclipse through such filters because they transmit infrared energy which can burn your eyes.

Although gelatin-film neutral density filters are protected by a thin lacquer coating, you should handle these filters only by the edges or at the extreme corners. The KODAK Gelatin Filter Frame, a two-part metal frame, is a convenient accessory for handling gelatin filters. You can use the filter frame with the KODAK Gelatin Filter Frame Holder, which you attach to your camera lens with an appropriate adapter ring. The filter frame holder is convenient to use because you can change filters rapidly, but it's not a necessity. You can attach the filter frame, or even the filters alone, to the lens with small strips of pressure-sensitive tape.



The KODAK Gelatin Filter Frame Holder and a KODAK Gelatin Filter Frame provide a convenient means for attaching gelatin-film neutral density filters to your lens. *These filters are not for visual use.*

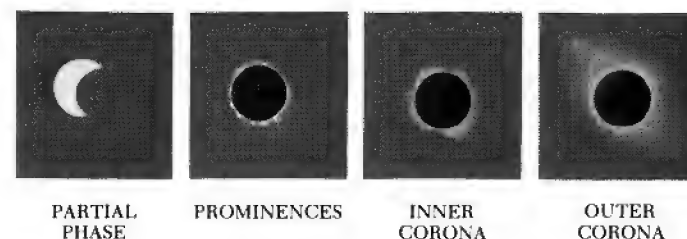
### Exposure Table

The exposure recommendations in the table on page 27 are based on results obtained in actual solar eclipse photography with clear viewing conditions. So much depends on atmospheric conditions, however, that you should regard these exposures only as approximate guides.

Exposure for each phase of the eclipse, especially during totality, can vary over a wide range and still produce good photographs. If you take several pictures at different exposure times and settings, each picture should show different details of the eclipse. Therefore, for the best coverage, bracket the suggested exposure. Take pictures at the estimated exposure and at 1, 2, and 3 stops less exposure and more exposure than the estimate.

You can calculate exposure times for lens openings other than those given in the table. Suppose the effective lens opening of your lens is  $f/32$  and the table suggests  $f/8$ . Divide 32 by 8 and square the answer:  $32 \div 8 = 4$  and  $4^2 = 16$ . Therefore a lens opening of  $f/32$  will require an exposure 16 times as long as that required at  $f/8$ .

The exposure time for movie cameras operating at a normal camera speed of 16 or 18 frames per second is about  $1/35$  second.



### Solar Eclipse—Approximate Exposures for Still and Movie\* Cameras

ASA Speed	Partial Phases		Totality (Prominences)		Totality (Inner Corona)		Totality (Outer Corona)	
	STILL	MOVIE	STILL	MOVIE	STILL	MOVIE	STILL	MOVIE
25—32	$f/5.6$	$f/11$	$f/3.5$	$f/8$	$f/3.5$	$f/2.8$	$f/3.5$	$f/1.4$
	5.0 ND 1/125	5.0 ND	No Filter 1/125	No Filter	No Filter 1/15	No Filter	No Filter 1/2	No Filter
40—50	$f/6.3$	$f/13$	$f/4.5$	$f/9.5$	$f/4.5$	$f/3.5$	$f/4.5$	$f/1.9$
	5.0 ND 1/125	5.0 ND	No Filter 1/125	No Filter	No Filter 1/15	No Filter	No Filter 1/2	No Filter
64—80	$f/8$	$f/16$	$f/5.6$	$f/11$	$f/5.6$	$f/4$	$f/5.6$	$f/2$
	5.0 ND 1/125	5.0 ND	No Filter 1/125	No Filter	No Filter 1/15	No Filter	No Filter 1/2	No Filter
125—160	$f/11$	$f/22$	$f/8$	$f/16$	$f/8$	$f/5.6$	$f/8$	$f/2$
	5.0 ND 1/125	5.0 ND	No Filter 1/125	No Filter	No Filter 1/15	No Filter	No Filter 1/2	No Filter
200—250	$f/16$	$f/9.5$	$f/11$	$f/22$	$f/11$	$f/8$	$f/11$	$f/2.8$
	5.0 ND 1/125	6.0 ND	No Filter 1/125	No Filter	No Filter 1/15	No Filter	No Filter 1/2	No Filter
400—650	$f/16$	$f/11$	$f/16$	$f/11$	$f/16$	$f/9.5$	$f/16$	$f/4$
	5.0 ND 1/250	6.0 ND	No Filter 1/125	1.0 ND	No Filter 1/15	No Filter	No Filter 1/2	No Filter
1000—1250	$f/16$	$f/16$	$f/16$	$f/16$	$f/16$	$f/13$	$f/16$	$f/5.6$
	5.0 ND 1/500	6.0 ND	No Filter 1/250	1.0 ND	No Filter 1/30	No Filter	No Filter 1/4	No Filter

\*The lens openings given for movie cameras are based on a normal camera speed of 16 or 18 frames per second.

Note: ND indicates neutral density filter.



## KODAK FILMS

For the partial phases, you can use any film intended for general photography. For the most interesting phases of an eclipse, those occurring during totality, a high-speed film is desirable. The following films are suggested for photographing the eclipse. You can use the ASA speeds with the exposure table on page 27 and with the formula on page 21.

KODAK Black-and-White Films—rolls	ASA speed
PANATOMIC-X.....	32
VERICHROME Pan.....	125
PLUS-X Pan.....	125
PLUS-X Pan Professional.....	125
TRI-X Pan Professional.....	320
TRI-X Pan.....	400
Recording 2475 (ESTAR-AH Base).....	1000
ROYAL-X Pan.....	1250

## KODAK Color Films—rolls

KODACHROME 40 5070 (Type A).....	25
KODACHROME 64 (Daylight).....	64
EKTACHROME 64 (Daylight).....	64
KODACOLOR II.....	100
KODACOLOR 400.....	400
VERICOLOR II Professional, Type S.....	100
EKTACHROME 160 (Tungsten).....	160
EKTACHROME 200 (Daylight).....	200

## KODAK Color Movie Films

KODACHROME Movie (Daylight) (8 mm, 16 mm).....	25
KODACHROME Movie (Type A) with No. 85 filter (super 8, 8 mm, 16 mm).....	25
EKTACHROME 40 Movie (Type A) with No. 85 filter (super 8).....	25
EKTACHROME 160 Movie (Type A)* with No. 85 filter (super 8).....	100
EKTACHROME MS 7256 (16 mm).....	64
EKTACHROME MS 2256 (ESTAR Base) (16 mm).....	64

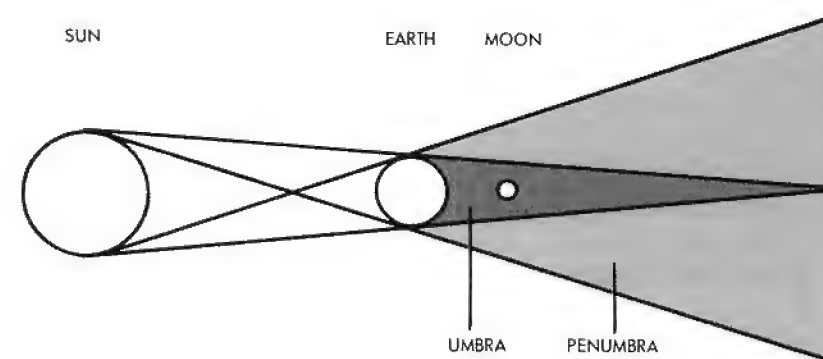
## KODAK Black-and-White Movie Films

PLUS-X Reversal 7276 with No. 85 filter (super 8).....	50
PLUS-X Reversal 7276 (16 mm).....	50
TRI-X Reversal 7278* (super 8, 16 mm).....	200
4-X Reversal 7277 (16 mm).....	400

Note: The No. 85 filter is built into most super 8 cameras and some 8-mm cameras. See your camera manual.

\*If you have a super 8 camera, see your camera manual or write to the manufacturer to determine whether you can use these films in your camera.

## CHAPTER III — LUNAR ECLIPSE



### General Procedures

A lunar eclipse occurs when the moon passes through the shadow of the earth. When the moon is within the umbra part of the earth's shadow (see illustration above), it is illuminated only by the light refracted through the earth's atmosphere. This light is usually orange or brick-red. Totality, the length of time the moon is totally within the umbra, may last as long as 1 hour and 40 minutes. Before the moon moves into the umbra, it passes through an area of partial illumination, called the penumbra. In the penumbra, the moon appears nearly the same as when it's in the full light of the sun.

It's easy to photograph a lunar eclipse. However, because the moon is so dim during totality, you should use a high-speed film. During totality, use the largest lens opening possible. This allows you to use shorter exposure times to stop the moon's motion in your photographs.

The moon may appear large to you, but when photographed through a lens of normal focal length, it will be a very small spot on the film. See page 7.

Use the lens with the longest focal length available for your camera, and support the camera on a steady tripod. To record details on the moon, take your pictures through a telescope, spotting scope, or a binocular. See Chapter I.

By making multiple exposures of the moon at regular intervals, you can obtain an interesting sequence showing the progression of the eclipse all in one photograph. To try this technique, you can either use a camera that allows you to make multiple exposures on the same frame of film; or you can alternately cover and uncover the lens. Check your camera manual. You should use a normal-focal-length lens so that you can get the whole series in one picture. Aim your camera so that the picture will include the path of the moon as the

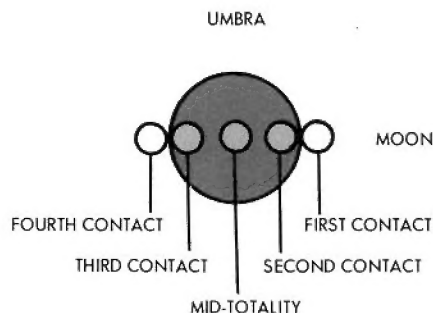
earth's rotation moves it across the sky from east to west.

To capture the sequence, begin taking pictures as the moon moves into the umbra. Make exposures at 6-minute intervals so that the images of the eclipse will be evenly spaced across the film frame. A normal-focal-length lens will cover an angle of view sufficient for about a 2-hour series of exposures. Since the images of the moon will be quite small, you may want to have an enlargement made. See picture on front cover.

A time-lapse motion picture record of the eclipse is interesting. Attach the movie camera and telephoto lens to a sturdy tripod or 2-axis telescope mounting. Expose 5 seconds of film every 5 minutes, carefully placing the image in the same place in the frame for each exposure.

### Lunar Eclipse Exposures

Lunar eclipses vary in duration and differ greatly in apparent brightness and color. Variations in atmospheric conditions and in the distance of the moon above the horizon may affect the moon's apparent brightness, making exact recommendations impossible. Use the exposures suggested in the table on page 31 as guides only. If the sky is hazy or if the moon is low in the sky, try doubling the recommended exposure time.



When you're taking single pictures of the moon, it's a good idea to bracket the estimated exposure for more assurance of properly exposed pictures. Try 1 and 2 stops more and less exposure than that recommended in the table on page 31.

When the moon is partially in the umbra, where you can see a definite shadow line across its surface, select the exposure for either the umbra portion or the penumbra portion. The film cannot properly record both areas at the same time.

Gradually increase the exposure from the second contact to mid-totality; decrease the exposure from mid-totality to the third contact. (See exposure table.)

You can calculate exposure times for  $f$ -numbers other than those given in the table. Suppose your largest lens opening is  $f/5.6$  and the table suggests  $f/2.8$ . Divide 5.6 by 2.8 and square the answer:  $5.6 \div 2.8 = 2$ , and  $2^2 = 4$ . This means the  $f/5.6$  lens opening will require an exposure 4 times as long as that required with a lens opening of  $f/2.8$ . For example, if the table suggests 1 second at  $f/2.8$ , you can use 4 seconds at  $f/5.6$ .

The moon appears to move a distance equal to approximately half its diameter in 1 minute. If the exposure time with a normal-focal-length lens is longer than 10 seconds, the moon motion is likely to be evident in the photograph. If you use a telephoto lens or a telescope with your

camera, the maximum exposure time must be even shorter.

You can use the formula below to determine the approximate maximum exposure time for sharp pictures of the moon with a telephoto lens or telescope.

$$\frac{\text{Focal length of normal lens}}{\text{Focal length of telephoto lens (or telescope)}} \times 10 = \text{Maximum exposure time in seconds}$$

For example, suppose the normal lens for your 35-mm camera has a focal length of 50 mm and you want to use a telephoto lens of 400 mm. Then  $\frac{50}{400} \times 10 = 1.25$ .

The answer, 1.25, means that the maximum exposure time for sharp pictures of the moon with the 400-mm lens is about 1 second.

Of course, longer exposure times can be used if you put your camera onto an equatorial telescope mounting that is driven to compensate for earth rotation. See pages 12–16.

### LUNAR ECLIPSE EXPOSURE RECOMMENDATIONS

ASA Film Speed	25–32	64–80	100–125	200	400	800–1000	1250–1600
Stage of Eclipse	25–32	64–80	100–125	200	400	800–1000	1250–1600
Full moon, clear sky	1/250 $f/5.6$	1/250 $f/8$	1/250 $f/11$	1/250 $f/16$	1/250 $f/22$	1/500 $f/22$	1/1000 $f/22$
Moon deep in penumbra up to FIRST contact and after FOURTH contact	1/60 $f/5.6$	1/60 $f/8$	1/60 $f/11$	1/60 $f/16$	1/125 $f/16$	1/250 $f/16$	1/500 $f/16$
At SECOND and THIRD contacts	2 $f/2$	1 $f/2$	1 $f/2.8$	1 $f/4$	1/4 $f/2.8$	1/8 $f/2.8$	1/15 $f/2.8$
MID-TOTALITY	8 $f/2$	4 $f/2$	2 $f/2$	2 $f/2.8$	1 $f/2.8$	1/2 $f/2.8$	1/4 $f/2.8$

See film suggestions on page 28.

Note: All exposure times are in seconds or fractions of a second. With KODACOLOR Films use 1/2 stop larger lens opening than indicated in the table.

## MORE INFORMATION

If you have additional questions about basic astrophotography, write to Eastman Kodak Company, Photo Information, Department 841, Rochester, New York 14650.

For more advanced technical data on astrophotography, write to Eastman Kodak Company, Scientific and Technical Photography, 343 State Street, Rochester, New York 14650.

A wide selection of Kodak pamphlets and books, including those listed below,

### KODAK Publications

KODAK Films—Color and Black-and-White (AF-1), \$3.95

KODAK Master Photoguide (AR-21), \$4.75

The Here's How Book of Photography (AE-100), "Moons in the Refrigerator" and "Shooting the Stars," \$10.95

KODAK Darkroom DATAGUIDE (R-20), \$8.95

KODAK Color DATAGUIDE (R-19), \$8.95

KODAK Color Films for Professional Use (E-77), \$4.00

KODAK Professional Black-and-White Films (F-5), \$3.00

KODAK Filters for Scientific and Technical Uses (B-3), \$3.50

Reciprocity Data: KODAK Color Films (E-1)

Reciprocity Data: KODAK Professional Black-and-White Films (O-2)

KODAK Plates and Films for Scientific Photography (P-315), \$2.50

KODAK Neutral Density Attenuators (P-114)

Photomicrography with KODAK EKTACHROME Professional Films (Process E-6) (P-305)

Every effort is made to keep publications in stock and available at all times. While we will attempt to ship your order more quickly, if we find we cannot supply the publications to you within 60 days, we will refund your money and try to give you a projected publication date so that you may reorder or make a substitution.

is usually stocked and sold by photo dealers. Try your dealer first. If the books you want are not in stock, you can order by title and code number directly from Eastman Kodak Company, Department 454, Rochester, New York 14650. Please send your money order or check with the order, including *your* state and local sales taxes. Prices shown are suggested prices only and are subject to change without notice. Actual selling prices are determined by the dealer.

## References

**Astronomy** (magazine suitable for beginners), AstroMedia Corporation, 411 East Mason Street, 6th Floor, Milwaukee, Wisconsin 53202. (See November 1976 issue: "Astrographic Cameras" and June 1977: "Observing with Binoculars.")

**Sky and Telescope** (magazine), Sky Publishing Corporation, 49 Bay State Road, Cambridge, Massachusetts 02138

**Popular Photography** (magazine), P.O. Box 2775, Boulder, Colorado 80323. (See October 1977 issue: "Make Your Own Astrophotographs.")

**Binoculars and All-Purpose Telescopes**, Henry E. Paul, Amphoto, New York, 1964. \$4.95

**Outer Space Photography for the Amateur**, 4th ed., Henry E. Paul, Amphoto, New York, 1976.

**Telescopes for Skygazing**, 3rd ed., Henry E. Paul, Amphoto, New York, 1976.

**Photography Through Monoculars, Binoculars, and Telescopes**, 3rd ed., Joseph D. Cooper, Amphoto, New York, 1965. \$2.95

**Skysighting: Photography for Amateur Astronomers**, rev. ed., Robert N. Mayall and Margaret W. Mayall, Dover Publications, Inc., New York. \$3.50, paperback

**Star Gazing with Telescope and Camera**, 2nd ed., George T. Keene, Amphoto, New York, 1967. \$4.95

**Astronomical Photography at the Telescope**, 3rd ed., Thomas Rackham, Faber and Faber Ltd, London, 1972. Available from Optica b/c Company.

**Astronomy with Binoculars**, James Muirden, Faber and Faber Ltd., London, 1976. £4.95, cloth; £2.75, paper

The following pamphlets are available from the Edmund Scientific Company:

**All About Telephoto Lenses**, Pamphlet No. 9036

**How To Use Your Telescope**, Pamphlet No. 9055

**Photography with Your Telescope**, Pamphlet No. 9078

**Time in Astronomy**, Pamphlet No. 9054

**All About Telescopes**, Book No. 9094

Note: These references are not available from Eastman Kodak Company.



### Some Scientific-Supply Sources

Write directly to the suppliers. This list does not include all such sources or imply endorsement by Eastman Kodak Company.

Celestron International, 2835 Columbia Street, Torrance, California 90503

Criterion Manufacturing Company, 331 Church Street, Hartford, Connecticut 06103

Edmund Scientific Company, 3775 Edscorp Building, Barrington, New Jersey 08007

A. Jaegers, 6915 South Merrick Road, Lynbrook, New York 11563

Maryland Academy of Sciences, 601 Light Street, Baltimore, Maryland 21230

Optica b/c Company, 4100 MacArthur Boulevard, Oakland, California 95619

Questar, Box EQ710, New Hope, Pennsylvania 18938

Unitron Instrument Company, 66 Needham Street, Newton Highlands, Massachusetts 02161

University Optics, Inc., 2122 East Delhi Road, Ann Arbor, Michigan 48106

### Astrophotography Travel

For other such travel opportunities, see astronomy magazines.

Stellafane, Springfield, Vermont

Amateur Observer's Society, c/o Glenn Schneider, 2520 Bouck Avenue, Bronx, New York 10469

Sitmar Cruises, 1801 South Hill Street, Los Angeles, California 90015

Astronomical League (national amateur society)

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